

Globular Clusters in the Sgr Stream and other structures

Michele Bellazzini

INAF - Osservatorio Astronomico di Bologna, Via Ranzani 1, 40127, Bologna, Italy

Rodrigo Ibata

Observatoire de Strasbourg, 67000 Strasbourg, France

Francesco R. Ferraro

Dip. di Astronomia, Univ. di Bologna, Via Ranzani 1, 40127, Bologna, Italy

Abstract. The possible association of Galactic globular clusters with the Sgr Stream is shortly reviewed at the light of the most recent observations of the Stream. $\gtrsim 20$ % of the Galactic globular clusters with $R_{GC} \geq 10$ Kpc are found to lie within or very nearby to the Sgr Stream as traced over the whole sky by the M giants from the 2MASS catalogue, in agreement with the results by Bellazzini, Ferraro and Ibata (2003a). Another possible association of outer halo globulars (NGC 1904, NGC 1851, NGC 2808, and NGC 2298) is also noted and briefly discussed.

1. Introduction

It is now clear that the disruption of the Sgr dwarf spheroidal galaxy (Sgr dSph) provided a non-negligible contribution to the assembly of the Galactic Halo (see Majewski et al. 2003, hereafter M03, Newberg et al. 2002 and references therein). Since the Sgr galaxy has its own globular cluster system it is natural to check if the Sgr dSph has also contributed to the building up of the Galactic globular cluster system. As a first attempt (Bellazzini et al. 2003a, hereafter Pap-I) we searched for correlations between the (X, Y, Z, V_r) phase-space distribution of the Galactic globulars having $10 \text{ kpc} \leq R_{GC} \leq 40 \text{ kpc}$ (Outer Halo globulars, OH) with the orbit and the N-body numerical simulation of the Sgr dSph computed by Ibata et al. (2001). The comparison was limited to the orbital path since present time to ~ 1 gyr in the past. A significant correlation was indeed found: the considered model orbit is a preferential subset of the phase space for OH clusters. The result strongly suggest that some of the OH clusters is associated with the Sgr Stream but its statistical nature prevents any firm conclusion about the individual clusters. Nevertheless, we could rank the clusters that are candidate members of the Sgr Stream according to their phase-space distance from the orbit.

Using the catalogue of the 2nd Incremental Data Release of the 2MASS survey we have tested two of our top-rank candidates, e.g. Pal 12 and NGC 4147 (Bellazzini et al. 2003b, Pap-II). We searched an excess of M giants similar to those found in the main body of the Sgr galaxy in the NIR color-magnitude diagram (CMD) of wide fields around the target clusters and we found a significant signal in both cases, showing that Pal 12 and NGC 4147 are immersed into the Sgr Stream (see Pap-II for details and references).

2. The All Sky view

Having at disposal the All Sky data release of 2MASS, M03 have traced the Sgr Stream over the whole sky using the M giants in a similar way to that adopted in Pap-II. In Fig. 1 we plot the distribution of the 2MASS M giants (selected in the same way as M03 and using their relations for the photometric parallax) in different projections of the Galactocentric cartesian coordinates. The OH clusters that matches the YZ distribution of Stream stars (the Stream is seen nearly edge-on in this projection) have been reported as large filled circles also in the other projections. It is quite clear that the majority of the selected clusters fits into the Stream distribution in any projection. Six of these clusters were also included in the list of best candidates of Pap-I. In the lower-left panel of Fig. 1 the distribution of radial velocities as a function of orbital longitude of the candidate clusters are compared with the predictions of the model by Ibata et al.(2001). As evident from the other plots the model has to be refined to correctly match the distribution of Stream stars, however the comparison is strongly suggestive. It is quite clear that some of the 10 clusters lying into the Stream has to be physically associated with the Stream. The comparison with the distribution of observed radial velocities along the Stream will soon discriminate between true physical associations and interlopers (see Majewski and Law, these proceedings). Therefore it seems quite firmly established that the disruption of the Sgr galaxy had a significant role in the assembly of the Galactic globular cluster system (see Pap-I). As far as individual clusters will pass the “radial velocity test” the properties of the original globular cluster system of the Sgr galaxy will become clearer and the early evolution of the galaxy could be more deeply investigated.

3. Other GC groups in the Outer Halo?

The four globular clusters associated with the main body of the Sgr galaxy constitute a remarkable overdensity in the phase-space distribution of OH clusters. The maximum mutual distance between any two of them is < 6 kpc and the maximum difference in V_r is $\simeq 50$ km/s. From a historical point of view it is quite interesting to recall that such a structure hasn’t been noted until the Sgr galaxy was discovered.

Is it possible that we are still overlooking similar substructures in the globular cluster system? If candidate Sgr Stream members are excluded (f.e. NGC 4147, NGC 5053 and NGC 5466 are quite close one to another in the X,Y,Z, V_r phase-space) there is only one group that shows remarkable clustering properties. The possible members of the group are NGC 1851, NGC 1904, NGC 2298, and NGC 2808. The distances of the latter clusters from NGC 1851

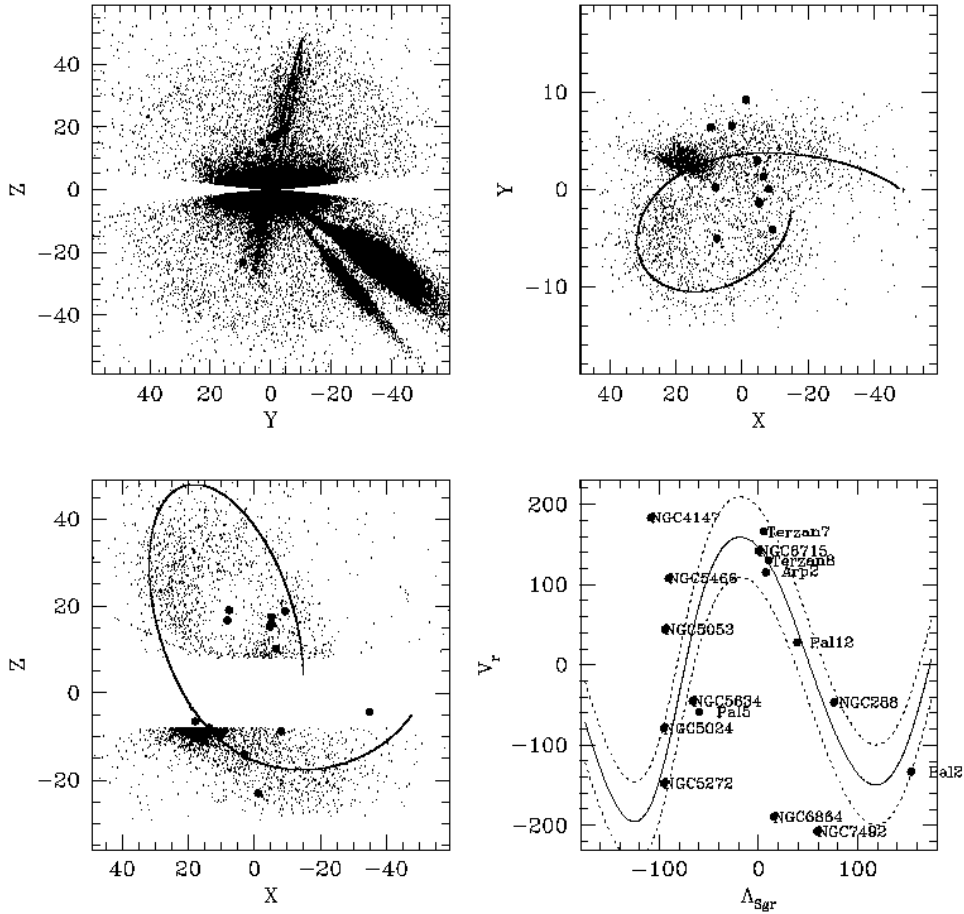


Figure 1. Upper left: YZ distribution of 2MASS M giants selected as in M03. The Sgr Stream is seen nearly edge on in this plane. The stars and clusters (filled circles) projected into the Stream in the YZ plane are reported in the XY and XZ planes (upper right and lower left). In the lower right panel the distribution of radial velocities as a function of orbital longitude of the candidate clusters are compared with the predictions of the model by Ibata et al.(2001). The path of the model orbit is reported in all the plots as a continuous line. It is quite clear that the model needs to be refined to correctly fit the observed spatial distribution of the Sgr Stream as traced by M giants. Excluding the known Sgr globulars (M 54, Arp 2, Ter 8 and Ter 7) there are 10 clusters that lie within or very nearby to the Sgr Stream. The measure of radial velocities along the Stream will easily discriminate between true physical associations and interlopers. In any case it is clear that a few clusters must be physically associated with the Stream. The two clusters that lie in the the hole of the ring formed by the Sgr Stream in the XZ plane are NGC 5634 and Pal 5 which are clearly not associated with the part of the Stream that is traced by M giants but may be related with older arms of the Stream (see Bellazzini et al. 2002 and Vivas, this meeting).

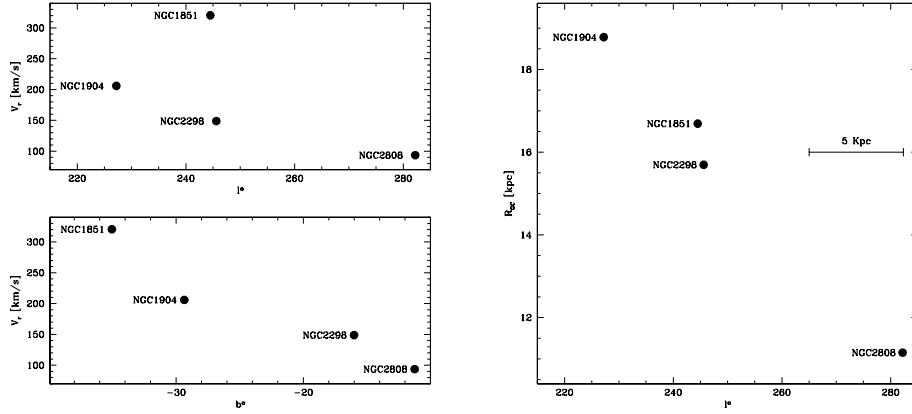


Figure 2. A remarkable possible association of OH clusters not related to the Sgr Stream. Left panel: Galactic coordinates vs. radial velocity. Right panel: Galactic longitude vs. Galactocentric distance. The mean mutual distance between the considered clusters is 6.2 ± 2.7 kpc.

are 3.5, 4.0, and 8.0 kpc respectively. The radial velocities of these clusters correlates quite well with their galactic latitude and their galactocentric distance correlates with galactic longitude (see Fig. 2, left panels). The metallicity is also quite similar ($[\text{Fe}/\text{H}] = -1.03, -1.37, -1.71, -1.11$) and all of them have an extended blue Horizontal Branch (HB). In particular, NGC 1851 and NGC 2808 are the only halo globulars with a *bimodal* HB. NGC 1261 is also nearby to the “group”, it has similar metallicity and blue HB morphology but it doesn’t fit so well into the correlations shown in Fig. 2. According to the method introduced by Lynden-Bell & Lynden-Bell (1995) NGC 1851, NGC 1904, NGC 2298, and NGC 2808 do not appear to have the same energy and angular momentum but they are relatively close to the Galactic Center and the approximation of the galactocentric velocity with the heliocentric velocity (that is quite relevant in this kind of analysis) may not be appropriate.

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